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EFFECTS OF PLANT POPULATION IN CASSAVA (MANIHOT ESCULENTA CRANTZ) AS INFLUENCED BY PLANTING METHODS

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EFFECTS OF PLANT POPULATION IN CASSAVA (*Manihot esculenta* Crantz) AS INFLUENCED BY PLANTING METHODS

by

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This thesis attached hereto, entitled "Effects of population in Cassava (Manihot esculenta Crantz) as influenced by planting methods" prepared and submitted by Khelikuzzaman bin Meera Hussain in partial fulfilment of the requirements for the degree of Master of Agricultural Science, is hereby accepted.

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6

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

The effects of two planting methods (20 cm cutting planted horizontally and 60 cm cuttings planted vertically) and plant populations ranging from 5,000 to 40,000 plants per hectare on the performance of two cassava varieties were investigated. The relationships of yield and yield components with plant populations were examined by fitting linear and quadratic regression equations to each planting method and variety.

Results of the experiment show that in both varieties, the horizontal planting yielded significantly better than vertical planting in terms of root and starch yields. The increase in root yield with variety MVen 119 was due to both increase in total root number and harvest index. In variety MCol 673 the increase in root yield was attributed mainly to increase in harvest index and decrease in shoot number. Variety MVen 119 outyielded MCol 673 in terms of root yield but the difference in starch yields between the two varieties was not evident. However, variety MCol 673 is favoured because of its higher starch content.

The yield response of the treatments to plant population showed that root yield declined with increasing plant population and that the yield was highest for the lowest population tested in the study. Yield reduction at high plant populations was generally attributed to the production of excessive shoots as well as to the decrease in mean root weight and mean root length.

Root number was enhanced by planting horizontally and it also showed an increasing trend with plant population which had been as-

certained to be quadratic.

Mean root length, mean root weight and root starch content differed between varieties but not between planting methods. Both varieties and planting methods did not show any significant effects on mean diameter of roots. Generally, high plant populations affected root development through decrease in root length, root diameter and mean root weight and also starch content of roots.

Harvest index was greater in horizontal planting than in vertical planting while plant height was not markedly affected by planting methods. The response pattern between plant population and harvest index, shoot number and plant height, showed that harvest index declined as population increased, whilst shoot number and plant height were enhanced.

CHAPTER I

INTRODUCTION

Cassava (*Manihot esculenta* Crantz) is thought to have orginated in tropical Brazil (Smith, 1968), from where it spread to other parts of South America and to countries bordering the Indian Ocean (India, Ceylon, Malaya, Indonesia, etc.) during the 18th Century (Jones, 1959). It is successfully grown in zones ranging from latitudes 30^{o} north and south and at elevations of up to 2,000 m, it is tolerant of temperatures of 18-35^{o}C, precipitation of 50-500 mm (Jones, 1959). World cassava acreage has steadily increased from 9 million hectares in 1966 to 12 million hectares in 1977 (FAO, 1968). Now cassava has found its extensive use where it feeds around 200 million to 300 million people (Coursey and Haynes, 1970). De Varies *et al*.(1970) in their review of productivity of various crops suggested that it is probable that cassava is potentially the most efficient calorie producer of the major crop species. Products from cassava roots such as starch and livestock feed are used in substantial and increasing quantities within and outside the tropical belt (Phillips, 1974). Cassava has assumed tremendous importance in recent years (Hendershott *et al*., 1972) and there are indications that it has great potential in alleviating future food and energy problems of the world (Hammond, 1977).

With the considerable expansion of the acreage under the crop, the demand for exact information on cultural methods has become urgent. Besides breeding for high yielding, pest and disease resistance varieties, it should be possible to substantially increase cassava yield by introducing correct agronomic practices such as optimum plant spacing. Considerable evidence has accumulated to show the quantitative relationships between plant density and crop yield and this has been reported by many workers (Bleasdale and Nelder, 1960; Holliday, 1960; Donald, 1963, Willey and Heath, 1969). In cassava, varying the amount of planting material does not reduce its marketable yield since the roots which are the marketable product, are not used for planting. Spacing experiments by CIAT (1973) have shown that a medium height type with few branches had a higher optimum plant population (about 10,000 plants/ha) than a very branched type of the same height and a tall type which had an optimum population of about 5,000 plants/ha. In other trials (CIAT, 1974) a plateau-type yield density response was obtained for non-vigorous varieties, while the vigorous types showed marked optima with lower maximum yield levels. When planted on a less fertile soil, the optimal density changed from 5,000 to 15,000 to 40,000 plants/ha and from 10,000 to 15,000 plants/ha for vigorous and non-vigorous varieties, respectively. Cock et al. (1977) indicated that root yield for some varieties increased up to 10,000 plants/ha followed by a flat response, though the reverse appeared to be true with other varieties that showed a well-defined optimum density of 5,000 to 10,000 plants/ha. Similar findings were reported by Verteuil (1917, 1918) where one cultivar had increased yield with an increase in plant density up to 12,000 plants/ha and other varieties showed a maximum yield only at that population. The results of spacing trials by other workers have also being shown to be equivocal, varying from a plateau-type response to a marked optima (Fernando and Jaysundera, 1942; Machado, 1951; Enyi, 1972a, Williams, 1972; Shanmugam, 1974; Kumar et al., 1975; Benvenuti, 1976). These studies thus indicate that different cultivars have different spacing requirements where low densities may favour vigorous cultivars which may not be as efficient as less vigorous ones at higher densities.

The results from various studies among research workers on planting methods did not show any consistent trend (Cock, 1974; Nestel, 1974). Jeyaseelan (1951) reported higher yields with vertical planting than with horizontal planting, and his findings confirmed those of Fernando and Jaysundera (1942), Jennings (1970), Hendershott *et al.* (1972), Chan (1977) and CIAT (1978). Takyi (1974) indicated that horizontal planting resulted in a non-significant yield increase over slant planting, but studies by Gurnah (1974) showed that planting position had no effects on yield. Chan (1977) who worked on different planting techniques with different length of cuttings found that the most suitable length of cuttings for horizontal planting was 20 cm and for vertical planting, 60 cm. It was suggested that long cuttings when planted horizontally produced excess shoots behaving as competitive individual plants and that their plant density was determined to some extent by shoot population. On the other hand, shoots in vertical planting behaved as branches channelling their photosynthates efficiently to a single main plant thereby giving better yields than horizontal planting. To date, little is known about the possible association between plant density and the two planting methods cited above. Apart from enabling the evaluation of such characteristics as optimum density and maximum yield it was suggested that density/yield relationships can facilitate comparison between different cultural methods (Willey and Heath, 1969). The latter aspect can be particularly useful when the factors being examined interact with plant density. As planting method may give considerable differences in final yield, it is desirable to know how it reacts to variation in plant density. It is also important to understand the optimal yields and the reaction of the yield components for planting methods and varieties when plant density was varied.

Thus, the present study examines the influence of two planting methods and different planting densities on the yield performance of three cassava varieties using the systematic spacing design of Bleasdale (1976). The planting methods were 20cm cuttings planted horizontally and 60cm cuttings planted vertically while the varieties were MVen 119, MCol 673 and MMex 52. In evaluating the yield response of these treatments to planting density, twelve varying plant populations ranging from 5,000 to 40,000 plants per hectare generated by the fan-shaped systematic spacing design were used. The influence of plant spacing variations on certain growth parameters such as shoot number, plant height, root number, root length, root diameter, starch content of roots and harvest index is also being considered for each planting method and variety.

CHAPTER II

LITERATURE REVIEW

1. Yield/density relationships in cassava.

Spacing studies with *Manihot esculenta* Crantz with respect to optimum plant density and yield have been conducted many times over the years. The results of these studies have been found to be conflicting both between countries and even in the same country and ecological zone.

In the trials in South America in two different states of Brazil, Silva (1970) recorded the best yield of roots at spacings of 1 x 0.4 m (25,000 plants/ha) and 1 x 0.3 m (33,300 plants/ha). However, Conceicao *et al*. (1973a) of Cruz Das Almas, Brazil from studies made between 1969 to 1972 recommended much lower densities of 16,600 - 20,000 plants/ha at spacings of 1 x 0.5 m - 1 x 0.6 m. Rodriguez *et al*. (1966) observed almost similar results in Misiones, Brazil where the optimum density obtained varied from 13,300 - 20,000 plants/ha. Studies in Colombia by Machado (1951) showed a non-significant yield increase when plant spacing was increased from 7,000 to 16,000 plants/ha. Recently trials by CIAT (1978) at four locations in Colombia involving four cultivars indicated that higher yields were obtained with higher densities up to 20,000 plants/ha. In two of the locations yield of three cultivars was lower at densities of either 8,000 or 11,000 plants/ha.

In Africa, Takyi (1972) found that spacings of 0.9 x 0.6 m and 0.9 x 0.9 m (18,500 - 12,300 plants/ha) on sandy loam Forest Orchrosol at Kwadaso, Ghana, gave significant yield increases over a wider spacing of 0.9 x 1.2 m (9,300 plants/ha). Later in 1973, Gurnah obtained the best yield at densities of 18,500 plants/ha planted at 0.6 x 0.6 m, and observed that spacings above or below 60 cm reduced root yields in the Forest Zone of Ghana. Gurnah's optimum spacing was closer than the 0.91 m generally recommended throughout Ghana (Doku, 1969). In Sierra Leone, Enyi (1972a) found that the optimal spacing for cassava was 0.9 x 1.2 m (9,300 plants/ha) but studies by Godfrey - Sam - Aggrey (1978) showed a wider spacing of 1.2 m x 1.2 m (7,000 plants/ha) to be the best. The data in Tanzania by Enyi (1972d) showed that the optimal density was 12,000 plants per hectare.

The results from spacing trials in Asian countries are also equivocal. Studies from India showed optimum density varies from 14 to 17 thousand plants/ha (Shanmugam, 1974) and 12,300 plants/ha as reported by Kumar _et al_. (1975). However, the Department of Agriculture, Thailand (1969) and MARDI (1976) of Malaysia both recorded the highest yields of cassava with lower densities of 10,000 plants/ha at a spacing of 1 x 1 m.

2. Factors influencing plant density effect on yield.

In view of the large variations in the optimum plant density between continents and countries and within each country, a number of reports (Vertuil, 1917, 1918; Normanha _et al_., 1950; Rodriguez _et al_., 1966; Williams, 1972; Enyi 1972c, 1973; Cock _et al_., 1977) have indicated that the relationship between total plant dry weight and plant density is a function of the age of the stand, of the genotype, of the number of shoots produced by the stem cutting and of the soil/ ecological conditions.

a. Age factor

The change of optimal plant density for root yield with plant age had been clearly elucidated by Williams (1972) and Cock *et al.* (1977). In a study of three Malaysian cultivars, Williams (1972) noted that marked increases in total dry matter yield occurred for all three genotypes up to plant density of 30,000 plants per hectare at nine months of age, but not at twelve months. Similar results have been obtained at CIAT for a range of Colombian cultivars, with one cultivar (MCol 1467) showing a decreased yield at high densities, after eleven months of growth (Cock *et al.*, 1977).

b. Genotype factor

A major factor influencing yield-population response curves is the genotype and this has been demonstrated by numerous workers. Vertuil (1917, 1918) found that one cultivar showed a marked decrease in yield as density was increased from 7,000 to 12,000 plants per hectare, a number of other types showed a maximum yield at 12,000 plants per hectare and one genotype showed little change in yield over the range of densities studied. As quoted by Cock *et al.* (1977), Calderon obtained increases in yield up to 30,000 plants/ha with one genotype and an almost flat response between 10,000 and 30,000 plants per hectare in another. Findings by Williams (1972) showed that after twelve months of growth the total dry matter yield of one genotype did not increase with population at densities greater than 6,000 plants per hectare, whereas for two others the yield increased as densities increased up to at least 13,000 plants per hectare. Similar findings were reported by Shanmugam (1974) for six cultivars and three spacings ranging from 15,000 to 22,000 plants per hectare.

The study indicated that three cultivars responded to the widest spacing whereas the other three yielded more with the intermediate density. Close spacing reduced yields in all the cultivars studied.

A study by CIAT (1975) on four different plant types suggested that total root production increased with an increase in plant density from 2,500 - 40,000 plants per hectare, but marked optimal yields were obtained for commercial root production. The optimal density was 10,000 plants per hectare for the short cultivars and the tall, non-branching cultivars, whereas for the tall, branching genotype it was 5,000 plants per hectare. Therefore, cultivars with a highly branched and spreading habit should be spaced further apart than those which are unbranched and more erect in form (CIAT, 1973; Onwueme, 1978). CIAT (1974) and Cock et al. (1977) proved that non-vigorous cultivars (such as MCol 22 and MMex 11) showed a plateau-type yield/density response from 10,000 to 30,000 plants per hectare whilst cultivars that are vigorous (such as MCol 1438, 1467, 1080) showed marked optima between 5,000 and 10,000 plants per hectare with lower maximum yields. It was commented that in a vigorous cultivar, there is a decrease in root yield after the optimal level of LAI had been exceeded due to excessive top growth which competes as a sink for assimilates with root. For a non-vigorous cultivar there is far less top growth with less leaf production, but with increasing plant density a compensatory point is reached whereby root production remains constant despite an increasing level of LAI and top growth.

c. Shoot number factor

Data presented by Enyi (1972a, b) demonstrated that shoot number has a considerable effect both on root yield and total dry matter. Enyi (1972a) showed that root yield of single shoot plants was significantly greater than that of multi-shoot at closer spacing (0.9 x 0.9 m) but the difference at wider spacings of 0.9 x 1.5 m and 0.9 x 1.8 m were not significant. Maximum yield of tubers was achieved in the single- and multi-shoot plants at a spacing of 0.9 x 0.9 m (12,600 plants/ha) and 0.9 x 1.2 m (9,450 plants/ha) respectively. The portion of total dry matter diverted into the root tubers was greater in single- than in multi-shoot plants, the reverse applying with regard to the portion diverted into the stems (Enyi, 1972b). The work by Enyi (1972c) also showed that at the spacing of 0.9 x 1.2 m single-shoot plants were superior to multi-shoot plants in tuber yield, individual tuber weight, ratio of tuber weight to stem weight, bulking rate, ratio of the tuber dry matter to total dry matter, net assimilation rate and relative growth rate. Multi-shoot plants, however, had greater leaf area and leaf area duration.

Contrary to the above findings on tuber yields, Fernando and Jaysundera (1942) proved that no differences in yield existed between single- and multi-shoot plants. Chan (1969a), however, demonstrated that plants which have naturally single shoots gave lower yields than multi-shoot plants at a spacing of 0.91 x 0.91 m. Using the same spacing, Chan (1970) showed similar results with multi-shoot plants, the latter being obtained by removing extra main shoots. Increased yield with multi-shoot plants were also reported by Mandal et al. (1973) and Shanmugham and Srinivasan (1973).

Hunt et al. (1977) in his comprehensive review mentioned that the development of multiple shoots from a stem cutting is to some extent equivalent to an increase in plant population. Because of the nature of the population/yield response curve, development of multiple shoots may be associated (a) with reduced yield (high population, Enyi, 1972a), (b) with no change in yields (intermediate population, Fernando and Jaysundera, 1942) or (c) with increased yields (low population, Chan 1969a, 1970; Mandal et al. 1973; Shanmugham and Srinivasan, 1973). In these relationships, the definition of low or high population must be made in relation to the population-yield response curve for single-shoot plant of the genotype being considered.

The reduction in yield of multi-shoot plants is probably due to the production of excessive leaf area and more stems, thereby altering the balance in favour of vegetative growth at the expense of tuberization. With a branched cultivar, pruning to a single shoot seems to give a yield advantage over multi-shoot plants (Enyi, 1972a), possibly because it reduces the competitive sink capacity arising from an excessive top growth which is non-contributory to root yield.

The similarity in yield between single- and multi-shoot plants as obtained by Fernando and Jaysundera (1942) may be associated with an increase in leaf area with higher plant densities (equivalent to multiple-shoots), while root yield remains constant after a certain density (CIAT, 1974; Cock et al., 1977). This suggests that a compensatory point is reached whereby root production remains constant despite an increased level of LAI and top growth.

Contrary to these observations the increase in yield in multi-shoot plants as demonstrated by Chan (1969a, 1970), Shanmugham and

Srinivaran (1973) and Mandal et al. (1973) could be the result of the maintenance of optimal leaf area for photosynthesis and a balanced utilization of assimilates for vegetative growth and tuberization. If the multi-shoot plants are unbranched and are unable to attain the required levels of LAI (Tan and Cock, 1979), they may produce numerous stems or shoots (Chan, 1977) to compensate for the lack of branches. If such an unbranched cultivar is pruned to a single stem, this leads to a reduced leaf area and hence a reduced root yield.

d. Soil/Fertility factor

Normanha et al. (1950) suggested that optimum plant density varied with soil conditions and later CIAT (1974) and Ribiero et al. (1974) both reported large variations in optimal spacings for different ecological zones. Trials at CIAT (1974), proved that non-vigorous cultivars showed a plateau-type yield/density response whereas the vigorous types showed pronounced optima with lower maximum yield. Where the soil is poor, the optimal density changed from 5,000 - 15,000 to 40,000 plants/ha and from 10,000 to 15,000 plants/ha for vigorous and non-vigorous varieties respectively. This suggests that because of the lower fertility, the foliage growth is less, and this allows for a closer plant spacing. One of the cultivar, MCol 1438 outyielded another cultivar, MCol 22 (a less vigorous cultivar) at all densities because of its higher vigour but without the undesirable inter-plant competition effects so apparent under fertile conditions. At CIAT, where the soil is more fertile, the vigorous cultivars were adapted to wider spacing, while the non-vigorous cultivars needed closer planting to achieve the required levels of LAI for maximal root bulking. However, more recently, in spacing trials at four locations of different fertility conditions, CIAT (1978) showed an almost flat-topped density/ yield response curve similar for all the locations and for different cultivars although yield levels were different.

Most experiments on the effect of plant density have been conducted at one rate of fertilizer application, but those where the interaction between fertilizer and plant density had been investigated, Normanha and Pereira (1950), had shown that fertilizer application had a greater effect at lower plant densities, while in other instances (Gurnah, 1973; CIAT, 1977, 1978) no interaction had been found.

3. The Relationship between Plant Density and Harvest Index, Plant Height and Some Yield Components of The Root.

a. Harvest index

The biological yield of a crop is the total yield of plant material (biomass) and in cassava the harvest index is the ratio of the yield of tubers to the biological yield. The harvest index which is based on harvest data at maturity generally indicates the relative efficiency of the plant in translocating and storing its assimilated carbohydrates in the economic or harvestable plant parts. The index has been a highly stable character as well as a good selection criterion for breeding work under ideal cultural conditions (Kawano et al., 1976). Tan and Cock (1979) found that a high harvest index could only be obtained by an improved partitioning of dry matter towards root growth and storage and also by the minimising of excessive top growth. CIAT (1973, 1974) reported that harvest index declined as plant population increased. A trial with three plant types by CIAT (1973) showed that the decrease was most marked as plant population increased in CMC 39 (tall type), and for Llanera (medium height, very branched type) the results were somewhat variable but showed the same trend. In CMC 84 (medium height type with few branches) the decrease in harvest index only occurred above a plant population of 15,000 plants/ha. In a study of vigorous and non-vigorous varieties at CIAT (1974), the decrease in yield of the former type with closer spacing was due to a decrease in harvest index suggesting that they produced an excessive top growth at higher populations. In non-vigorous varieties a decreasing harvest index at more than 10,000 plants/ha was compensated for by increased dry matter production.

b. Plant height

One of the commonest expression to show the effect of competition is the effect of density on plant height. Height gives competitive advantage by enabling the shading of neighbours. In cassava, plants were much taller at high plant populations than at lower ones (Enyi, 1973, Cock *et al*., 1977) indicating that as density increases and competition for light is intensified, plant height was substantially increased.

c. Some yield components of the root

Cock *et al*. (1977) found that root number per plant decreased with plant population, but there was little difference between varieties in root number per unit area above 5,000 plants/ha, though number per plant and individual root weight decreased as plant population increased. In another trial with five varieties, root number per plant tended to be rather constant between 5,000 and 10,000 plants/ha and then declined